

# **Advanced numerical methods for realistic river plume modeling in coastal-scale domains**

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## **LONG-TERM GOAL**

The long-term goal of this research is to realize the potential for realistic-domain numerical models as tools for prediction and understanding of the dynamics and transport processes in the coastal ocean.

## **OBJECTIVES**

The overall objective of this research program is to improve the robustness and fidelity of three-dimensional models of river plumes. This involves several steps, including:

- Development of idealized and realistic "test problems" involving the dynamics of river plumes
- Application of a particular model, ROMS, to these test problems, using it to investigate sensitivity to forcing, boundary conditions, resolution, and model algorithms (e.g., turbulence closure, advection schemes)
- Comparison of the model with specific data sets (e.g., the Eel River outflow, the Gulf of Maine Coastal Current)

## **APPROACH**

This project is a cooperative effort between Rocky Geyer at WHOI and me. I have been involved primarily with model development, running and testing, while Geyer supplies guidance and insight. The initial modeling involves an idealized domain, performing a set of tests to define the appropriate input conditions for a river plume. It was not known a priori how much detail in the estuary was required to provide a realistic specification of the river-mouth flow and salinity. The next step is to determine the sensitivity to horizontal grid resolution and numerical advection scheme, and to determine the requirements for a 'grid-converged' solution.

After the model configuration has been established, we address specific components that lead to realistic simulations. These include wind stress forcing, tides, ambient flow in the coastal ocean, and time-variation of river flow.

The final step is to perform realistic simulations, using data sets from the Gulf of Maine and the Eel River shelf.

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## **WORK COMPLETED**

The exploration of the input conditions for the river plume have been completed. The sensitivity to horizontal grid resolution and advection scheme are essentially complete, yielding "grid converged" solutions. We have started exploring the influence of tides and wind-forcing on the plume results.

## **RESULTS**

The investigations of the model boundary conditions have yielded important information about estuarine dynamics and their impact on plumes. These are important both for the understanding of how estuaries work and for the implementation of boundary conditions for river plume models. The key finding is that the exchange condition at the mouth of an estuary is very insensitive to the amount of mixing in the estuary. This result is reminiscent of the venerable paper by Stommel and Farmer (1952) on "overmixing", in which they note that there is a certain level of mixing above which the exchange flow at the mouth will remain constant. Our model simulations indicate that the "overmixed" condition is not exactly obtained, but the exchange flow is very insensitive to the amount of mixing in the estuary. This means that the details of the estuarine regime do not need to be included in a model in order to obtain a realistic representation of the boundary conditions at the mouth. The magnitude of the exchange flow does have to be properly specified, which is set by the buoyancy flux from the river and the depth at the river mouth.

## **IMPACT/APPLICATION**

Our improved understanding of the boundary conditions for river plumes will provide significant improvements in the realistic modeling of river plumes. Previous simulations of plumes have inadequately treated the estuarine boundary condition, however the constraints for accurate specification of this condition were not fully understood. Even a recent study by Yankovsky (2000), which highlights the importance of correctly simulating the estuarine exchange, uses an inflow boundary condition that does not control the amount of fresh water entering the domain. Our new results allows a realistic estuarine boundary condition to be applied to plume models without the computational burden of including an extensive estuarine reach into the model domain.

## **TRANSITIONS**

I have developed numerical algorithms for implementing fresh water sources (i.e., rivers) and tides, both of which have become part of the standard ROMS releases. I have also developed new boundary conditions for estuarine simulations, which will become part of the ROMS distribution, and have also been active in testing the new pressure gradient routines that have been released in the latest version of ROMS.

## **RELATED PROJECTS**

I am working on ROMS development through the Navy's System of Experts. I am also working with Rich Signell (NATO/SACLANT) and Dennis McGillicuddy (WHOI) on realistic simulations of the Gulf of Maine, focusing on the buoyant coastal current system.

## REFERENCES

Stommel, H. and H. G. Farmer. (1952) Control of salinity in an estuary by a transition. J. Mar. Res., **12**, 13-20.

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